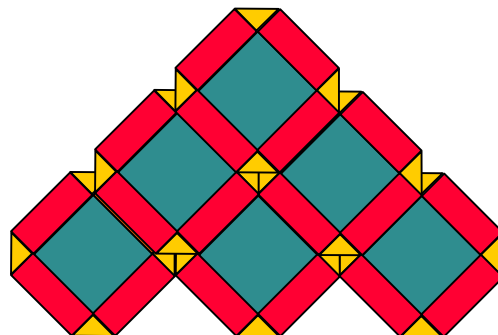


# Automated Package Delivery

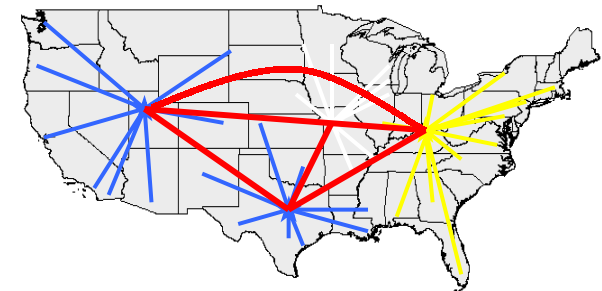
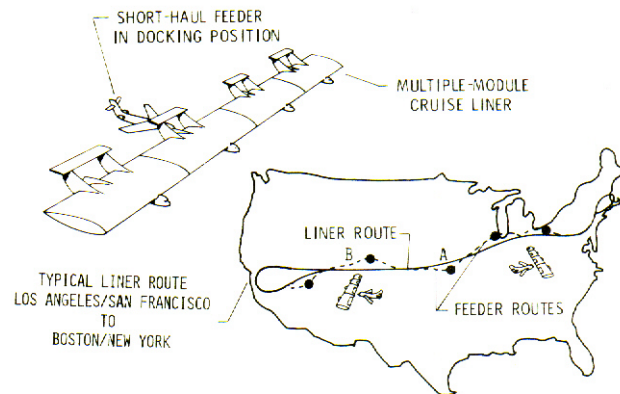
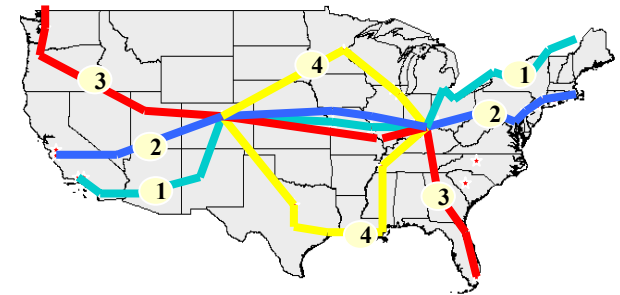
October 2, 2001



**Paul A. Gelhausen**  
**p.a.gelhausen@larc.nasa.gov**

# Presentation Outline

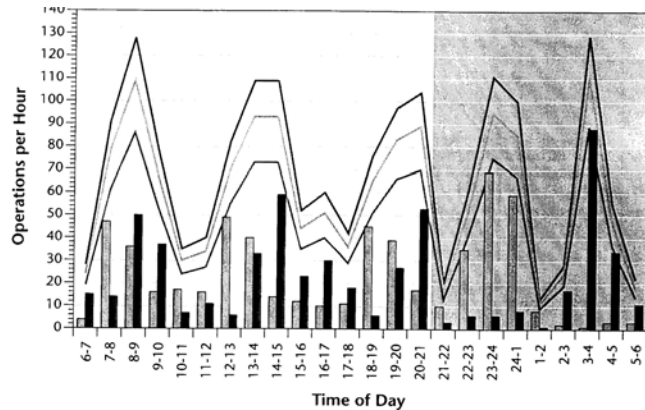
- **Mission Overview**
  - Motivation
- **Study Overview/Status**
  - Mission Concept Definition
  - Baseline vehicle development
  - Revolutionary technologies identified
  - Summary



## Mission Overview

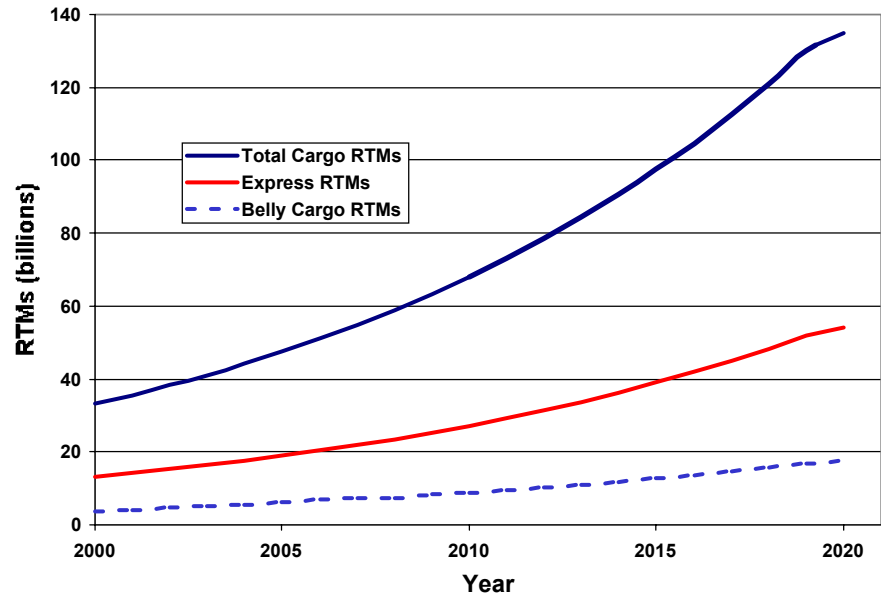
- **The growth in express package delivery is nearly double the growth in air-transport of passengers.**
  - The prevailing system architecture relies on a hub-spoke model that optimizes for cost.
- **At the current rate of growth, several airports will soon be capacity limited. Growth of the air-cargo market will be constrained by the number of operations, and the infrastructure at the hub.**
- **The proposed mission model is highly modular and distributed.**
  - Allows for increased utilization of underused airports
  - Reduces the overall capacity requirements of the ground infrastructure
- **This project is related to the OAT Goal to Revolutionize Aviation.**

# APD Mission Motivation



- Fed Ex's Memphis operation is approaching daytime capacity.
- As the business grows, airport capacity will soon be exceeded.

- LMI's analysis of the growth in air cargo was based on conservative economic growth.
- Total capacity of the system will need to grow by a factor of 4 in 20 years.
- Capacity needs will not be met by excess volume on passenger transports



## *APD Overview/Status*

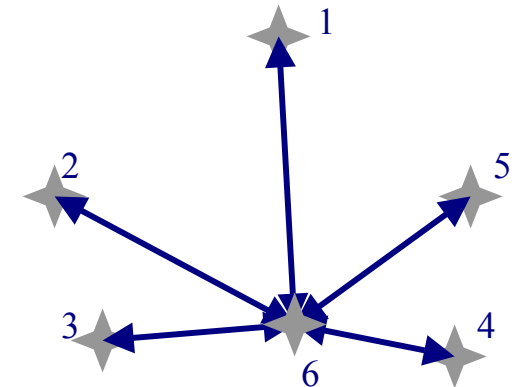
- **The APD study has developed a better understanding of the mission requirements and has developed two vehicle concepts.**
- **Assuming that air-carriers are going to run into cost issues associated with further expansion. An opportunity for a new operational concept will be acceptable.**
- **Increased system capacity, without significant cost in time is the goal.**
- **LMI was tasked to perform a market analysis and mission definition. Task completed in February '01.**
- **A SAMS task to develop concepts that performed the mission as defined by LMI was completed in June '01**

## *APD Network Comparison*

### Hub and Spoke Network

Assumptions:

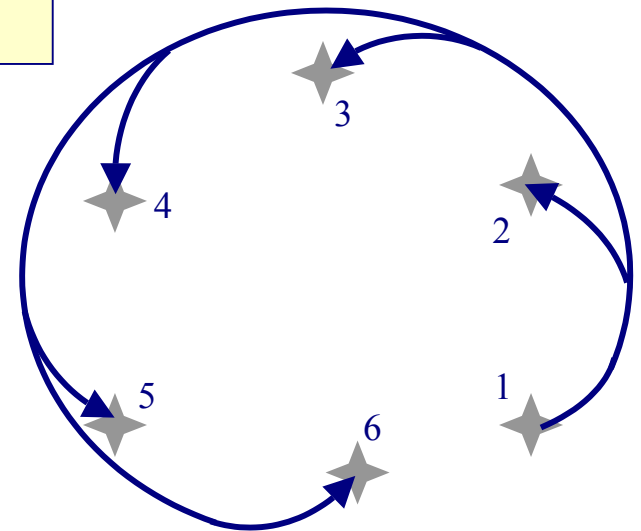
- 6 node network
- Each node delivers and receives a load (L) each day
- 5 aircraft required
- Each aircraft with capacity of L



### Point to Multi-Point Network

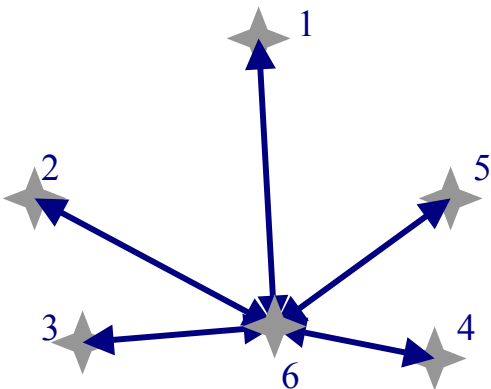
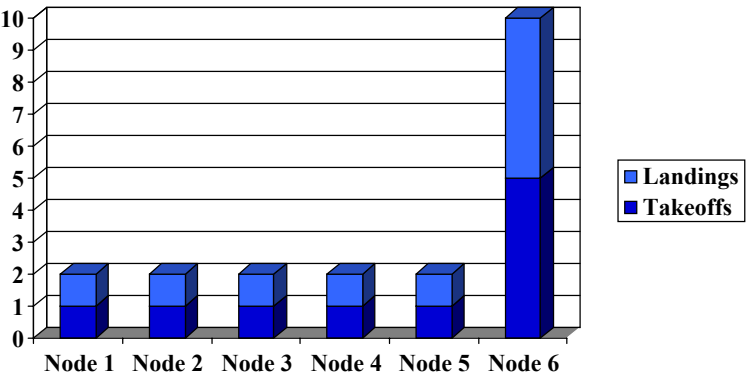
Assumptions:

- 6 node network
- Each node delivers and receives a load (L) each day
- 1 Tow Vehicle and 14 Delivery Vehicles required
- Each aircraft with capacity of 0.2 L



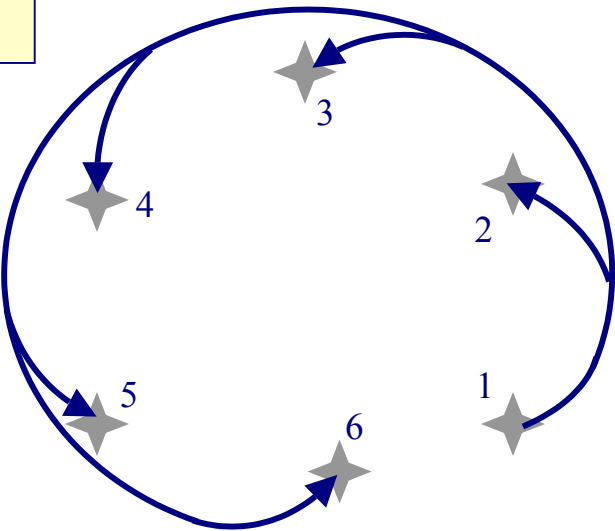
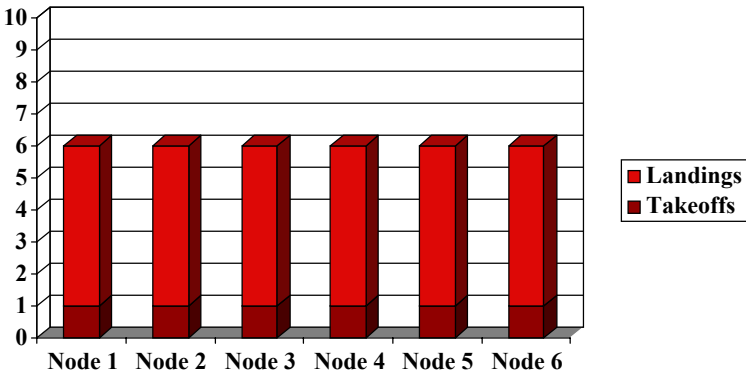
Hub and Spoke Network

Operations



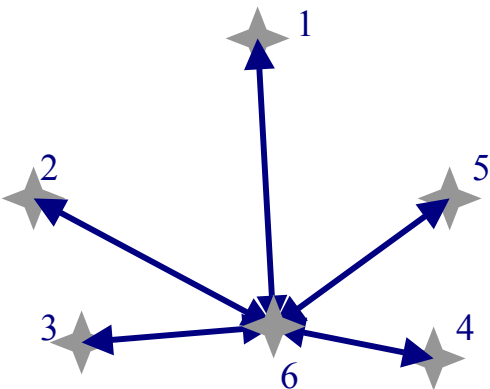
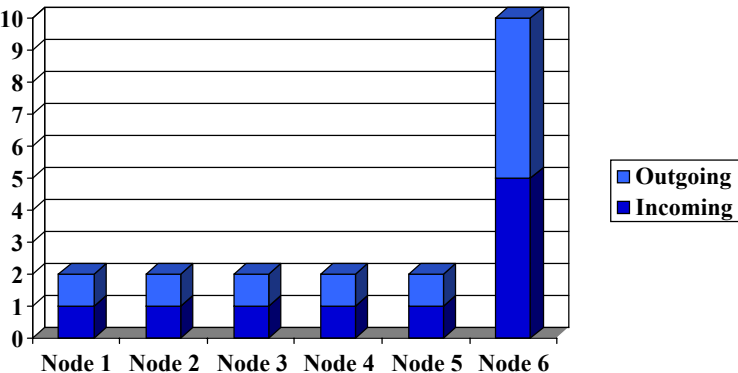
Point to Multi-Point Network

Operations



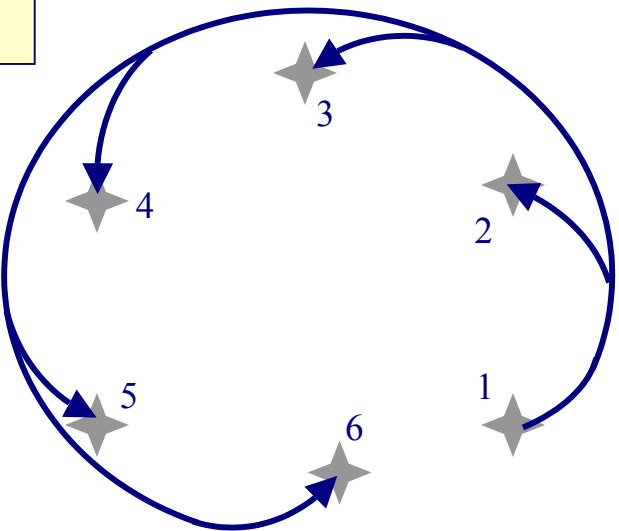
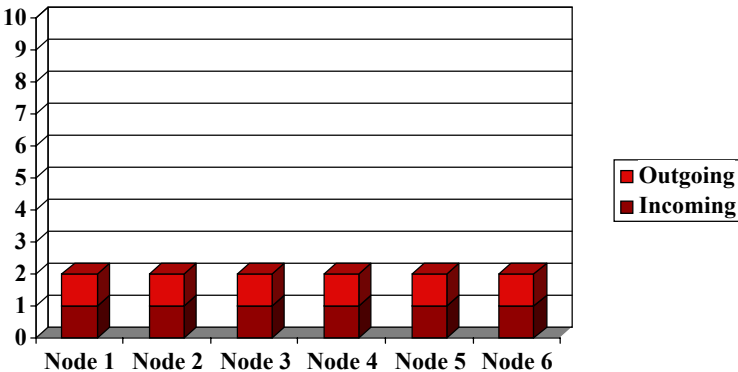
Hub and Spoke Network

Load  
Processed



Point to Multi-Point Network

Load  
Processed

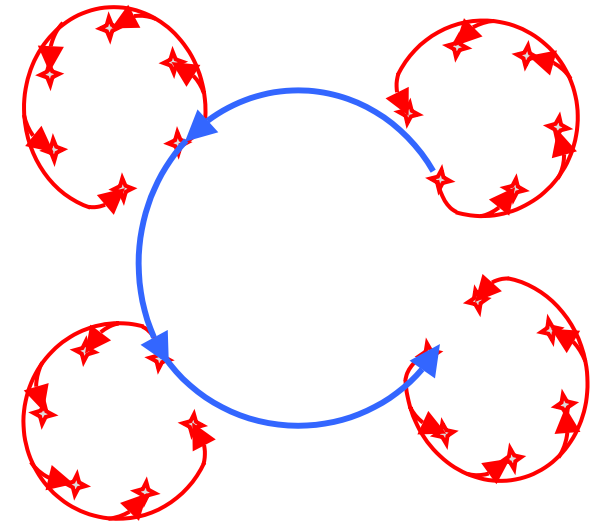




## *APD Conclusions of the LMI Study*

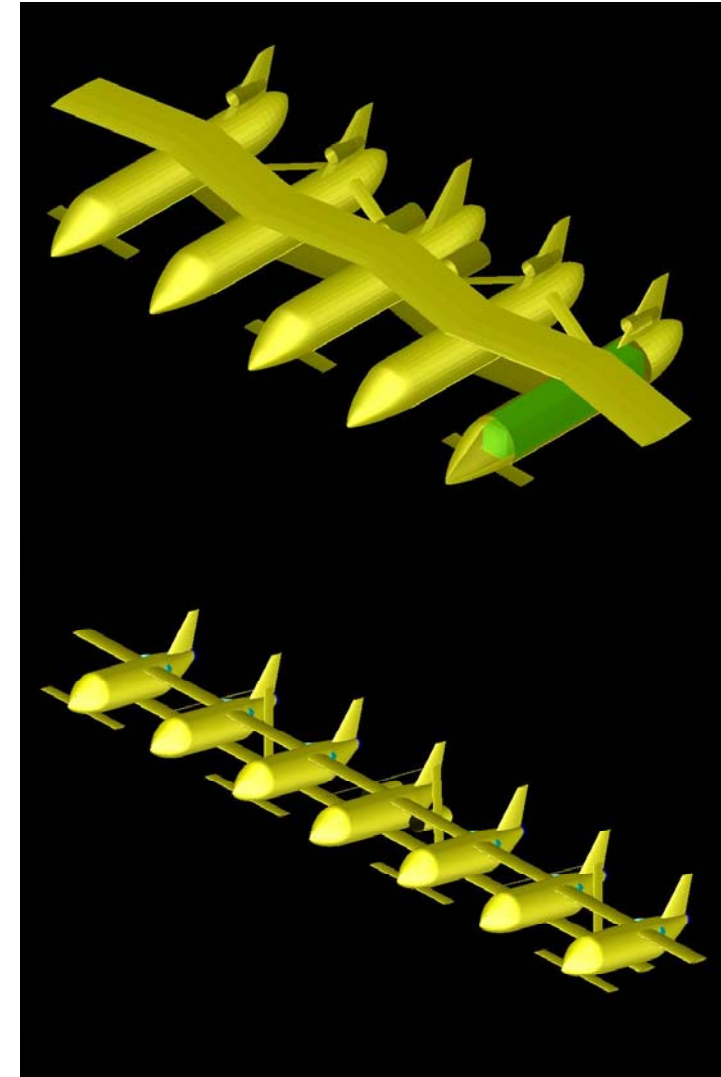
- The Hub and spoke architectures in use today are highly effective for the given objective.
- Growth will exacerbate current congestion
  - Likely extension of the hub and spoke architecture
    - will be capital intensive
    - may lead to service degradation due to congestion, and
    - risks constraining economic growth.
- Point to Multi-Point (PMP) architectures have the potential to resolve some of the issues.
- Properly focussed technology thrusts could help PMP be economically competitive.

### Linked Point to Multipoint Concept



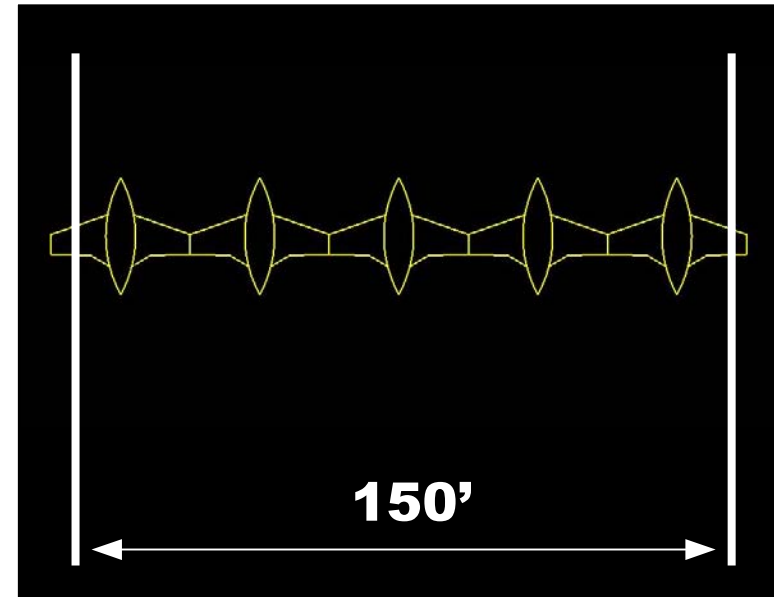
## *APD Aircraft Concept Task*

- Two APD vehicle concepts that build on the current Fed-Ex paradigm has been developed.
  - One that does the same job as a DC-10
  - One that could replace several Caravans
- Operational concepts require that the aircraft maintain a high degree of interchangeability.
- Concepts can carry standard sized containers.
- Aircraft were sized to existing runway requirements.
  - Taxi loads and segment hanging off the end led to biplane/joined tail configuration
  - Smaller payload aircraft can accommodate more segments



## Long Range Concept Study

- Roughly equivalent to attaching 4 Gulfstream II's with wider fuselages, to a 737-200 with a third less span and 757 engines



### Final Weights (lb)

	Tow Vehicle	Inside child	Outside child	Total Assembled Aircraft
Fuel weight	30,000	10,040	9,917	69,915
Shared mission fuel	22,328	7,646	7,646	52,913
Individual mission fuel	7,672	2,394	2,271	9,330
Operating Weight	52,089	30,077	28,382	169,007
Payload	20,000	20,000	20,000	100,000
<b>GW</b>	<b>102,089</b>	<b>60,117</b>	<b>58,299</b>	<b>338,922</b>

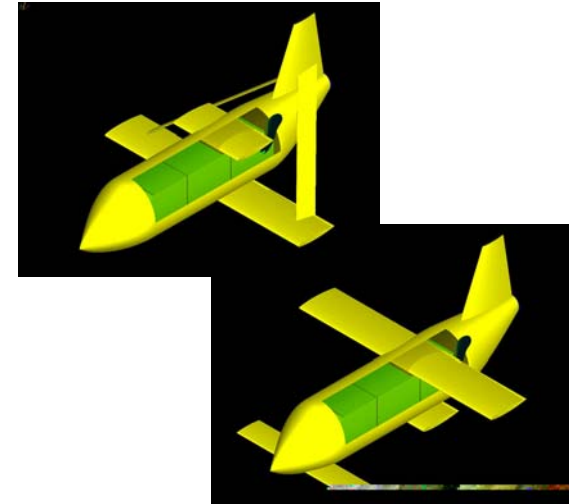
### Overall Parameters

Total Thrust	64,400	7,083	6,838	92,242	lb
T/W	0.63	0.12	0.12	<b>0.27</b>	
Payload Fraction	0.20	0.33	0.34	<b>0.30</b>	
W/S	113.4	66.8	64.8	<b>75.3</b>	lb/ft2

## “Town & County” Study

### Typical Mission:

- Detroit – Cleveland – BWI – Charlotte –Atlanta –  
Memphis – St. Louis – Chicago
- 2061 miles, shortest leg = 95 sm, longest leg = 360 sm



### Final Weights (lb) – 35,000 lb payload

	<i>Tow Vehicle</i>	<i>Low Joined Wing</i>	<i>High Wing</i>	<i>Total Assembled Aircraft</i>
Fuel weight	6,000	1,771	1,771	16,626
Shared mission fuel	4,861	1,138	1,138	11,689
Individual mission fuel	1,139	633	633	4,937
Operating Weight	12,561	5,779	5,779	47,235
Payload	5,000	5,000	5,000	35,000
<b>GW</b>	<b>23,561</b>	<b>12,550</b>	<b>12,550</b>	<b>98,861</b>

### Overall Parameters

Total Thrust	14,600	2,900	2,900	32,000 lb
T/W	0.62	0.23	0.23	<b>0.32</b>
Payload Fraction	0.21	0.40	0.40	<b>0.35</b>
W/S	107.1	57.0	57.0	<b>64.2 lb/ft2</b>

# APD Technology Requirements

- **Revolutionary technologies identified to enable the APD system.**
  - **Reliable autonomous flight**
    - *Concept will be much too costly if a pilot is required to fly each delivery vehicle.*
  - **Adaptable flight control**
    - *Every flight segment will require the controls to reconfigure to accommodate the varying characteristics of the aircraft*
  - **Highly reliable connect/disconnect mechanisms**
    - *Must have 100% confidence in the connections and separations*
  - **Opportunities for alternate concepts to address integration problems**
    - *So far the study has only investigated 2 different payload options*
    - *Need new ideas to improve the integration with the runway*
  - **Aerodynamics and propulsion optimization**
    - *Biplane/span-loader concept works, but open to other ideas.*
    - *Want to integrate concepts from PAVE engine studies.*

## *APD Study Summary*

- **The point to multi-point (PMP) vehicle is an interesting solution to the projected air-cargo capacity problems.**
  - **Significant increase in total system capacity, without large increase in ground infrastructure**
  - **Levels the usage of ground based facilities**
- **A modular concept that can perform the mission has been developed**
- **Recommendations**
  - **More simulation and cost analysis of the current concept will expose more advantages and technology requirements**
  - **Alternate configurations, and alternate mission concepts, around the PMP concept might show different economies of scale. (Specifically, the cross-examination of PAVE concepts and technologies.)**